Part 651 – Animal Waste Management Field Handbook

Chapter 10 – Agricultural Waste Management System Component Design

IL651.1007 (f) Composting Dead Animals

Where not specifically addressed in this Illinois Supplement, size facilities for composting dead animals using the NRCS References listed below, to meet or exceed the provisions of the Illinois Dead Animal Disposal Act, Section 90.110. All composting facilities will have a primary and secondary stage. The primary stage may be implemented using any of the options listed below. Implement the secondary stage using static or forced air bins.

Calculate the design daily mortality rate using the greatest projected mortality rate of any given 90-day period during the year. Break down the daily mortality rate by size, type, and/or age of animals to get the total daily mortality rate for the operation. If information on mortality is not available from the producer, use the design mortality rate and carcass design weight values from Reference [2].

Static Bin System Composting

Generally, turning and mixing of the static pile in the bin system is avoided until most of the decomposition has taken place in the primary stage. The guidance in this supplement is geared toward animals such as finishing hogs and feeder cattle, which generally take 90 days for the primary stage. Smaller carcass sizes will compost more quickly (as fast as 10 days for a 3 lb. body size, 35 days for a 50 lb. body size and 61 days for a 150 lb. body size.) Larger animals will take longer if left full size (up to 194 days for a 1500 lb. body size.) [Reference 3]

Compute the minimum available capacity of the primary composting bins by multiplying the design daily mortality rate (pounds of dead animals per day) by a volume factor. In general, the designer should use a volume factor of 20 cubic feet per pound of dead animals per day for larger animals, such as swine and cattle. This will yield enough space for 90 days of mortalities in a well-managed composting system with an appropriate carbon to nitrogen ratio (C:N ratio). If a nitrogen source such as poultry litter or manure is used, the volume factor may be reduced as low as 10 cubic feet per pound of dead animals per day [Reference 2]. If nursery pigs or other smaller animals are the only mortalities being composted, the 20-cubic foot volume factor and the 90-day primary and secondary composting period may be adjusted down. Likewise, if larger animals such as dairy cows, are being composted, the volume factor and composting time period may need to be adjusted up. [References 1 and 2]

Account for the angle of repose of the material in the bin when calculating the available bin capacity. In the absence of actual data, use an angle of repose of 1:1 (45 degrees.) Note that a narrower bin width will mean less volume lost to the angle of repose.

The Illinois Dead Animal Disposal Act ("the Act") also requires the following minimum composting area:

Type of Animal Carcass	Area of Composting Required
Swine	Min. 10 ft^2/1000 lbs. of carcass to be composted in a 3-month period, with a minimum of 10 inches between the carcass and any vertical bin walls
Cattle, sheep, goats	Larger of: • 1 ft. of space provided all around the carcass, AND • 1 ft. wider than the width of the equipment used for turning the compost pile

The minimum number of primary and secondary bins required for a bin-only system is typically:

- Primary Bins = (No. of bins for 90 days Mortality) + 1
- Secondary Bins = No. of Primary Bins
- Total Bins = Primary + Secondary
- Minimum System Design = 4 Bins total

Additional bins may also be provided for storage of carbon source materials. Dead animal bodies have a C:N ratio of about 10:1, meaning that significantly more carbon will be needed in the mix to achieve the 25:1 to 40:1 ratio needed for proper composting [Reference 1]. The carbon source material is also typically used as a bulking agent, to allow some air movement in the pile and facilitate microbial action. Examples of good carbon sources for composting include wood shavings or chips, sawdust, corn stover, and chopped straw. The material can also help in maintaining the necessary 40-65% moisture content required for composting.

The total number of bins may be reduced depending on the producer's management and use of the composting system. Achieving the proper temperature is the goal of composting – the timeframe may vary depending on the animals composted, how often the compost pile is turned, management of proper moisture content, and the C:N ratio.

Although the partially composted material from the primary stage will generally experience some volume reduction, the secondary bins are typically designed to be the same size as the primary bins for ease of management: secondary bins may be used as primary bins if needed in the sequence, and the same equipment may be used to load and unload the bins.

Depending on management, the secondary composting time can be shorter: as little as one-third of the time required for the primary stage. However, because it is advisable to allow a minimum of 30 days' additional storage time for the compost to finish curing, the secondary stage is generally taken to be equal in time to the primary stage. [Reference 3]

Finished compost may be reused in the primary composting stage for up to 50% of the carbon source material. This creates a use for the finished compost, plus it will inoculate the new compost with the bacteria that breaks the mortalities down.

Planning

Talk to the producer to ensure the designer has accurate animal types, weights, ages, and mortality rates for each type/weight of animal.

Ensure that the producer has an idea of how much carbon source/bulking material will be needed for operation of the composter, and a reliable source of that material. As mentioned in the Illinois Dead Animal Disposal Act, about one cubic foot of carbon source will be needed for every 10 lbs. of carcass. For example, a single 150-pound hog carcass would require about 15 cubic feet of carbon source material for composting – this is equivalent to a cube measuring about 2.5 feet in all directions.

The type of carbon source makes a difference in the amount of material needed to reach the optimal C:N ratio. The 20-cubic foot volume factor was developed using sawdust. Wood chips have less available carbon, so more carbon material needs to be used per pound of mortality. See the Operation and Maintenance of a Bin Composter below for more information on C:N ratio.

The interview sheet in Appendix C may be useful during the planning for a mortality composter, to ensure that the sizing is done correctly.

Composting Sequence

1. The primary bin will be filled and allowed to compost for 90 days after the last carcass is placed, or until the temperature in the area of the last carcass placed falls below 130°F after a period of temperatures in the range of 135°-160°F. If the temperature does not reach at least 135°F after 7 days of composting, the pile should be turned and more water or carbon source should be added to achieve a moisture content that will allow the composting process to proceed.
2. Move the material finished with primary composting to a secondary bin. Add more carbon source as necessary to maintain desired moisture content.
3. Allow the material to reheat through a second composting cycle in the secondary bin for 90 days. Add more carbon source and/or water as necessary to maintain desired moisture content over the secondary composting period.

Filling the Primary Stage Bins

A minimum layer of carbon source should be placed on the floor of the bin prior to loading the first carcasses and on the sides and on top of the carcasses. Maintain this thickness on the sides and top during the composting process. The minimum thickness of the carbon source is as follows:

Type of Animal Carcass	Required Minimum Thickness of Carbon Source
Swine	10 inches
Cattle, sheep, goats	12 inches

Any cattle, sheep, or goat carcass weighing over 300 lbs. is required by the Act to be processed prior to covering with the carbon source by opening the abdominal cavity and incising the large limb muscles, or other methods to increase the contact of carbon source with the carcass, hasten composting, and reduce distension of the carcass. Carcasses of those animals dying of suspect neurological causes are not to be composted.

The time to completely fill a primary bin will depend on the bin size and rate of mortalities being produced. In addition, the scheduling of bin use and degree of inactivity in a bin will depend on the number of days' worth of mortality volume that each bin will hold. A bin that holds a larger number of days' worth of mortalities results in more inactivity. To maximize bin scheduling efficiency, select an effective bin volume that can evenly multiply to 90 days (such as 30 or 45 days' worth of mortality volume). Figures 1 and 2 show examples of the composting sequence of two different primary bin sizes. In Figure 1, the primary bin volume holds 30 days of mortalities, while in Figure 2 the primary bin volume is 70 days of mortalities.

<u>Forced Air Bin System Composting</u>

The forced air bin system composter may be selected from the list of approved products in Exhibit B. Select a product with capacity adequate to handle the design daily mortality rate determined above, using manufacturer's recommendations.

Forced air composting is very similar to static bin composting. The main difference is that the composting piles are actively aerated. Where static bins require the material to be turned to increase the oxygen in the pile, forced air composters do not require turning. Each bin has an air pump that blows air into the compost pile from pipelines that are connected to the floor. The addition of oxygen increases microbial activity in the compost.

Forced air composting takes less time to complete the composting cycle for primary and secondary bins. The composting still needs to reach the same temperatures as in a static bin, but forced air composting piles are able to increase to the required temperature sooner and stay above this temperature longer. It is important that each forced air bin receives the required amount of oxygen or else the compost piles will become anaerobic and composting cycle will not be completed. Air pumps that are used in this system need to be able to work under large static pressures and be durable. The table below shows the pump requirements for a forced air bin system.

Pump Requirements	Acceptable Range
Air Flow, free (empty bin)	15 – 30 cfm
Air Flow, fully loaded bin	8 cfm – 20 cfm @ 72” H_2O
Standard Operating Pressure	10” – 80” H_2O
Maximum Back Pressure	90” – 140” H_2O

Because of the addition of air to each pile, other key variables for forced air composting are different from those of the static bin system. Some of these ranges do not meet the requirements of the Dead Animal Disposal Act, which were developed for static bin system technology. Forced air systems allow lower carbon to nitrogen ratios and can handle higher mortality loading rates; the Illinois State Veterinarian has approved the use of the forced air bin system for NRCS projects. The following table shows the required criteria for forced air mortality composting bin systems.

Composting Variable	Acceptable Range for Forced Air Bin System
Consecutive days above 150° F	10 days minimum
C:N Ratio	20:1 to 30:1
Cubic Yards Carbon/1,000 lbs. animal carcass	1.55 CY to 2.55 CY (as compared to 3.7 CY for static bins)
Mortality Loading Rate (Volume Factor)	Maximum 16.2 lbs. mortality/ft^3 of bin volume
Days Composting – Primary Bins	28 - 45 days
Days Composting – Secondary Bins	21 – 45 days
Re-Use of Compost for Carbon Source	20% - 50%

Compute the minimum capacity of each primary composting bin for the forced air system by multiplying the design daily mortality rate (pounds of dead animals per day) by the days to fill a bin to get a total mortality weight for the design period. Divide that total mortality weight for the design period by the mortality loading rate (MLR) from the above table. Note that the mortality loading rate was developed for swine mortalities. If mortality from other species are to be composted, work with the manufacturer to determine an appropriate loading rate.

MLR for each primary bin can be used instead of a volume factor (VF) for designing a forced air composter. As stated above, the volume factor for static bins is usually 20 CF/lbs/day. The volume factor for forced air composters is approximately 2.4 CF/lb/day. The correlation between these factors can be seen with this equation:

$$VF = (1/MLR)*\text{days to fill a primary bin}$$

Use the guidance for static bin system composting (above) to determine the following for the forced air bin system; the concepts are the same:

- Accounting for the angle of repose of the material in the bin;
- The minimum number of primary and secondary bins required;
- Planning the volume and type of carbon source material;
- The composting sequence;
- The process for filling the bins.

Forced Air Bin System Composting with Mixing Grinder

The addition of a mixing grinder to the forced air composting system essentially changes the handling of the mortalities before placing them in the composting bin. The mortalities are mixed with the carbon source and finished compost at a 3:2:1 ratio, respectively. The batch is then placed in a mixer and ground. The ground-up product is then placed in a primary composting bin that will be aerated with air pumped into the bin from below. The guidance below supplements the above section on forced air bin system composting; many of the concepts are the same. All the guidance for forced air bin system composting applies to the system with mixing grinder except as noted below.

The mixing/grinding procedure offers advantages to the forced air bin composting system. The composting process starts more quickly and is more complete when the mortalities are preprocessed with the mixing grinder method. The minimum days in primary composting bin is 15 days (down from 28 days without the grinder.) The secondary bins have a minimum processing time of 14 days and they do not have to be aerated. New research has found that the microbial activity in the batch is robust after the primary composting (when using the mixing grinder) and that additional aeration is not required for the temperature to get above 130 degrees for the required 5 consecutive days.

The pump requirements are the same as listed for the forced air composting bin system. Pump and airflow specifications apply only to the primary bins for this system. Secondary bins will not be required to have aeration. The following table shows the required criteria for the forced air bin system with mixing grinder.

Composting Variable	Acceptable Range for Forced Air Bin System with Mixing Grinder
Consecutive days above 150° F	5 days minimum
C:N Ratio	22.5:1 to 30:1
Ratio of Mortality: Carbon Source: Finished Compost (on a weight basis)	3:2:1
Mortality Loading Rate (Volume Factor)	Maximum 17.5 lbs. mortality/ft^3 of bin volume
Days Composting – Primary Bins	15 days
Days Composting – Secondary Bins (not aerated)	14 days

The composting recipe is a ratio of 3 parts mortality to 2 parts carbon source to 1 part finished compost, by weight. These ingredients should be added to the grinder before mixing so that the liquid from the mortalities will be soaked up by the carbon source and finished compost. For example, if 1500 lbs. of mortality are being composted, 1000 lbs. of carbon source and 500 lbs. of finished compost should be mixed with the mortalities before grinding. For startup activities where there is no finished compost available, use additional carbon source instead of finished compost, and recognize that some adjustments may need to take place if the monitored temperature and/or moisture are outside of the target ranges.

The mortality loading rate in the table is to assist in sizing the primary composting bin. The primary composting bin should not exceed this loading rate because the aeration system may not function properly. This mortality loading rate comes out to 12,000 lbs. of mortalities per batch, for a bin with the dimensions of 16' length x 9.5' width x 6' height.

Compute the minimum capacity of each primary composting bin for this system in the same way as for the forced air composter without a mixer/grinder. If a volume factor (VR) for the forced air composter with mixing grinder is required, calculate the VR as shown in the previous section. The volume factor should be approximately 0.85 CF/lb./day.

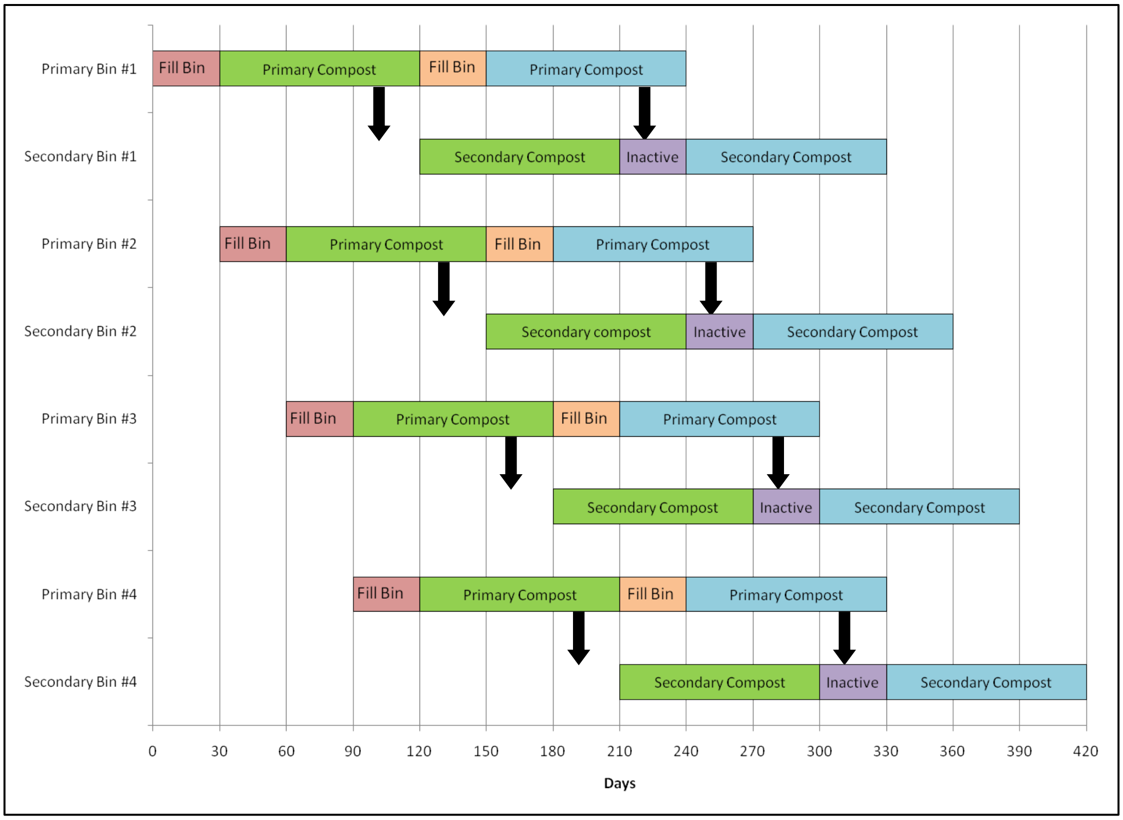

Figure 1. Example composting sequence for 30-day capacity bins

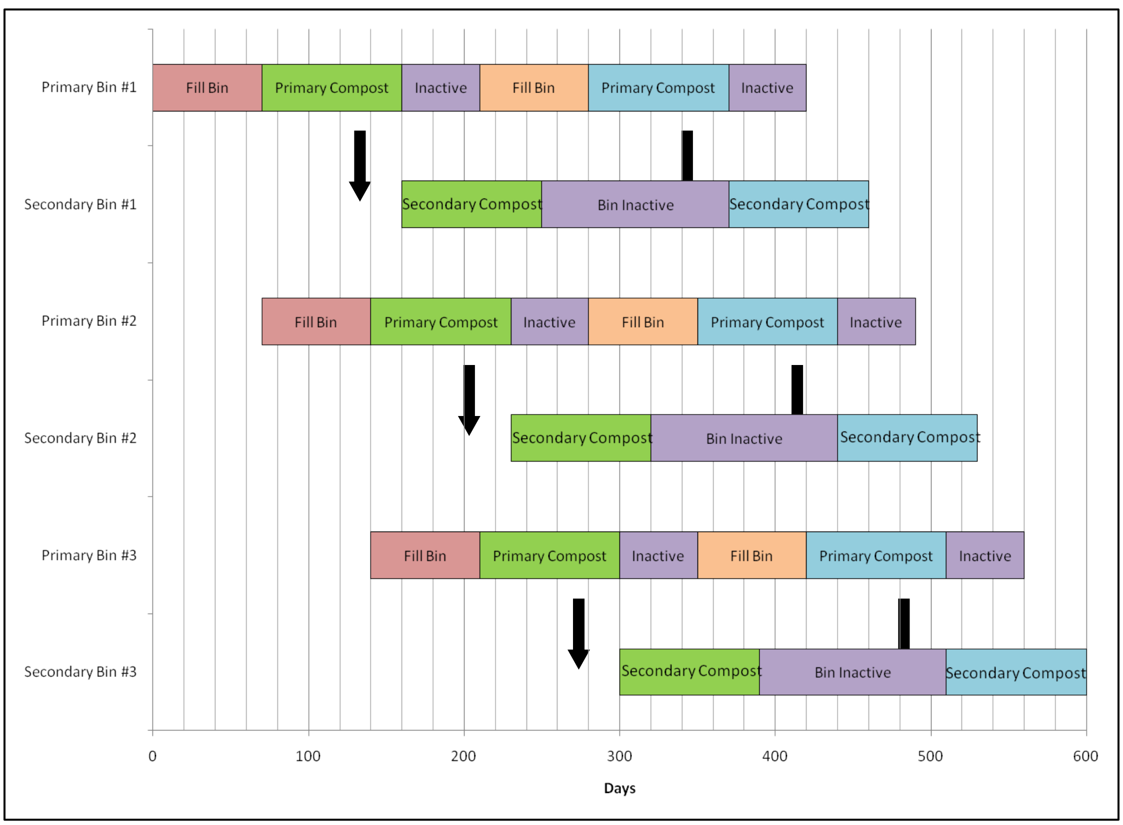

Figure 2. Example composting sequence for 70-day capacity bins

Operation of a Bin Composter

The operation instructions are very important for composting systems. The instructions should include both the primary and secondary bins. Some general considerations include:

1. Typically, coarse sawmill sawdust, shredded cornstalks, coarse-ground corn cobs, and other materials possessing like properties and having similar particle size are recommended for the carbon source due to their high bulk, ease of handling, absorbency and high carbon content. Straw and very fine sawdust are recommended with reservation because the fine texture of these materials restricts proper air movement, and straw will flatten out.
2. Do not use treated wood material because the treatment will kill the aerobic bacteria that are needed to accomplish the composting.
3. Provide a recommendation for a startup recipe and operation. Determining the best recipe for the operation will require some initial experimentation. The initial compost mix should result in a carbon to nitrogen ratio between 25:1 and 40:1. A suggested startup mix for composting of swine mortalities is 3.7 cubic yards of carbon source for each 1000 lb. of carcass. Modify this information if a forced air bin system is planned.
4. Provide a recommendation for monitoring of moisture in the bins. To meet NRCS Conservation Practice Standards, the moisture content of the compost mix must be maintained at 40-65% by weight (wet basis), to enable the aerobic bacteria to work effectively. Too much moisture in the mix prevents adequate oxygen content and inhibits the composting activity. Add bulking material to create a more porous mix whenever moisture content begins to approach the upper limit and monitor more frequently until moisture content is successfully brought back down to the desired range.
5. Measurement of moisture content may be done by visual observation if the producer has experience with silage production. Proper silage moisture content is approximately 65%, so the operator would need to make sure that the mix does not get quite that wet. Another method is to take some compost material in your hand and squeeze it. Compost at proper moisture content should stick together in a ball. If it falls apart, it is too dry; if it expands or moisture squeezes out, it is too wet.
6. Provide a recommendation for monitoring of temperature. Illinois NRCS Conservation Practice Standard 316 states that the temperature of the primary and secondary piles need to reach at least 130° F for 5 consecutive days. The Illinois Dead Animal Disposal Act specifies that the compost temperature must reach 135° to 160°F during the composting cycle and be recorded daily. For the forced air bin system, the temperature will most likely reach the higher end of this range (at least 150°F) for the required period. If the compost pile is not reaching the target temperature for the required amount of time, the problem can usually be remedied by adding more bulking material; in some cases, the pile may need to be turned as well to restart the process.
7. Take immediate action when a pile approaches 185°F. Spontaneous combustion is a serious risk, and the high temperature is also a problem for the survival of the composting bacteria. High temperature can usually be corrected by adding water.
8. For the secondary stage bins, compost temperature should again reach at least the target temperature and then cool to a temperature lower than 100°F.
9. Once the compost material has passed the secondary stage, it is ready for final use. Some of the finished compost may be retained for reuse (up to 50% of the carbon source) in the primary composting stage of a new batch.

In-vessel Composting

The in-vessel composter may be selected from the list of approved products in Exhibit A. Select a product with capacity adequate to handle the design daily mortality rate determined above, using manufacturer's recommendations.

Sizing the Secondary Bins

For the selected in-vessel composter product, design the capacity of the secondary bins to handle the output of the in-vessel composter when running at full capacity (which may be higher than the design daily mortality rate), to account for instances when higher than average mortality is experienced.

Use the manufacturer's predicted rate for output volume of primary stage compost per day. This will be less than the theoretical output of the device if calculated based strictly on available volume and cycle time, because during proper operation, there will be significant air space in the vessel to allow for proper moisture control and aerobic bacteria composting activity. Also, a volumetric reduction takes place during the primary composting phase in the vessel.

Plan for a percentage of the primary stage compost to be recycled back into the in-vessel composter along with any bones that have not been fully processed, to be used as part of the carbon source for new mortalities. Use manufacturer's recommendation for this percentage.

Sizing of the secondary bins may be done as follows:

1. Determine the daily production volume (cubic feet per day) of primary stage compost to be moved into secondary processing, by applying the manufacturer's recommended percentages and rates as described above.
2. Select a bin size that will work for the producer, taking into account available equipment and management style.
3. For the selected bin size, calculate the available volume of each bin. In the absence of actual data, use an angle of repose of 1:1 (45 degrees.) Note that a narrower bin width will mean less volume lost to the angle of repose.
4. Determine the number of days' worth of storage each bin represents, by dividing the available bin volume by the daily production volume.
5. Determine process and storage time. Plan for the secondary treatment to take 90 days. This is conservative. If appropriate for the planned management of the system, add up to 60 days' worth of storage capacity for each batch of compost, to accommodate scheduling of land application, for a total of up to 150 days that a batch of compost will occupy the secondary bin after the bin is completely filled.
6. Calculate total cycle time by summing the number of days to fill the bin with the process and storage time determined above. This cycle time represents the amount of time until each bin can be emptied and used again.
7. Calculate minimum number of secondary bins needed, by dividing the total cycle time by the number of days to fill the bin. Add an extra bin if desired, for storage of carbon source.
8. The minimum number of secondary bins required is two.

Operation and Maintenance of an In-vessel Composter

The operation and maintenance instructions are very important for the in-vessel composting system and should rely heavily on the manufacturer's recommendations. The instructions should include both the primary device and the secondary bins. Some general considerations include:

1. Typically, wood chips or shavings are ideal carbon sources due to their high bulk, ease of handling, absorbency and high carbon content. Straw or sawdust are not recommended because these materials are too fine and do not allow proper air movement, and straw will flatten out. However, use the manufacturer's recommendations for carbon source.
2. Do not use treated wood material because the treatment will kill the aerobic bacteria that are needed to accomplish the composting.
3. Provide a recommendation for a startup recipe and operation. The initial compost mix should result in a carbon to nitrogen ratio between 25:1 and 40:1. Use manufacturer's instructions. Determining the best recipe for the operation will require some initial experimentation.
4. Provide a recommendation for monitoring of moisture in the in-vessel unit. To meet NRCS Conservation Practice Standards, the moisture content of the compost mix must be maintained at 40-65% by weight (wet basis), to enable the aerobic bacteria to work effectively. Manufacturer's recommendations may vary; the resulting instructions should meet both NRCS standard and manufacturer's recommendations. Too much moisture in the mix prevents adequate oxygen content and inhibits the composting activity. Add bulking material to create a more porous mix whenever moisture content begins to approach the upper limit and monitor more frequently until moisture content is successfully brought back down to the desired range.
5. Measurement of moisture content may be done by visual observation if the producer has experience with silage production. Proper silage moisture content is approximately 65%, so the operator would need to make sure that the mix does not get quite that wet.
6. Provide a recommendation for monitoring of temperature. Some in-vessel composters contain built in thermometers for this purpose. Illinois NRCS Conservation Practice Standard 316 states that the temperature of the primary and secondary stages need to reach 130º F for 5 consecutive days. The Illinois Dead Animal Disposal Act specifies that the compost temperature must reach 135° to 160°F during the composting cycle and be recorded daily.
7. For the secondary stage bins, compost temperature should again reach at least 135°F and then cool to a temperature lower than 100°F.
8. Adjustment of the basic recipe is done by observation of the color of the completed primary stage compost, as instructed by the manufacturer. In general:

    Chocolate color is desirable

    Tan color means add more recycle materials

    Coffee color means add more fresh carbon source

<u>References</u>

1. NRCS National Engineering Handbook Part 637, Environmental Engineering, Chapter 2 - Composting
2. NRCS National Engineering Handbook Part 651.1007, Agricultural Waste Management Field Handbook
3. The Ohio State University Extension. 2006. Ohio's Livestock Mortality Composting Manual

EXHIBIT A. Approved Product List – In-vessel Composters

This product list represents information provided to Illinois NRCS by vendors of in-vessel composter products and is not all inclusive.

Product	**Manufacturer and Contact**	**Size Range** *(smallest and largest)*	**Capacity** *(lbs./day carcass)*
Biovator	Nioex Systems USA, Inc http://nioex.com/biovator	BIO308: 16' long x 3' dia … BIO442: 42' long x 4' dia.	60 500
Ecodrum	Tri-Form Poly, Inc http://www.ecodrumcomposter.com/	Model 260: 22' long x 5' dia. … Model 560: 55' long x 5' dia.	300 750
Marting Mfg.	Marting Mfg. of Iowa, Inc. http://www.marting.com/products/composting.html	MM412: 12' long x 4' dia … MM540: 40' long x 5' dia *custom sizes available	150 750
Rotoposter	Rotary Composters http://RotaryComposters.com	516SL: 16' long x 5' dia … 1040: 40' long x 10' dia *custom sizes available	215 (swine) 320 (poultry) 425 (ground) 1,715 (swine) 2,570 (poultry) 3,425 (ground)

EXHIBIT B. Approved Product List – Forced Air In-Bin Composters

This product list represents information provided to Illinois NRCS by vendors of forced air in-bin composter products and is not all inclusive.

Animal Type	**Manufacturer and Contact**	**Bin Sizes**	**Capacity** *(lbs. carcass/bin)*
Swine	Advanced Composting Technologies, LLC http://advancedcomposting.com/	10 ft. x 16 ft. x 6 ft.	8,000 lbs. to 12,000 lbs.

EXHIBIT C. Interview Sheet for Planning a Mortality Composter

The following questionnaire may be helpful in determining the design size and type of mortality composting facility. Each site and operation will be different, and the talking points in this list are not all-inclusive.

- What type of composter is planned?
  - Static bin system
  - Static bins with roof
  - Forced air bin system
  - Forced air bin system with mixing grinder
  - In-vessel system with secondary bins

- Will the composter be used for handling occasional significant death loss occurrence on the site? For example, if the site has a typical death loss of 3% but has an outbreak where the mortality rate increases to 6%, will the composter be used for these extra mortalities or will another form of mortality management be used (i.e. rendering, burial, etc.).

- How many of each type of livestock will be served by the mortality composter? Be as detailed as possible FOR THIS SITE. Use actual animal loss data from the site. For example, if 80% of all the mortalities for a wean-to-finish site happen within the first three weeks, separate out this weight and age range to improve the accuracy of the composter sizing.

Livestock Type	Weight Range (lbs.)	Age Range (wks, mths or yrs)	Mortality Rate (animals/day)

- What type of carbon source is available for the composting? Is there enough? It takes lots of material to do a good job of composting.
  - Wood chips or shavings (without tannin; avoid oak, cedar, or redwood)
  - Sawdust (without tannins)
  - Corn stover
  - Chopped straw

- Other ____

- ☐ Where will the carbon source be stored? At least 3 months of carbon source should be available on site and stored in an area that is covered so that it will not get saturated.

- ☐ What is the proposed end use of the finished compost material?
  - Land apply as fertilizer according to a nutrient management plan
  - Bag and sell
  - Reuse as carbon source in composting system.
  - Other ____